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ABSTRACT

Aspects of the Total-System Design (TSD) approach to instructional design in medical laboratory science that was implemented at Creighton University are described. In a four-year project, TSD principles were used to produce the uniform, systematic, and complete definition of a medical technology major within a program of study leading to the B.S.M.T. degree. TSD involves the application of systems science principles to the analysis of needs and to the delivery of instruction in educational programs. Faculty members used a precise language of instruction and a top-down approach to define the knowledge, skills, and attitudes essential to entry-level generalist practice in medical laboratory science. The TSD approach involves the extension and adaptation of the familiar behavioral objectives to produce formal goal statements with several parts: the complexity of the subject matter, the performance level at which the student will be tested, and the relative difficulty of the unit in terms of concentration and initiative required. The top-down analytical process begins with the concept of an ideal entry-level practitioner (graduating student). Each goal statement is further specified by a branching tree of substatements until the content level is reached, and specific instructional activities also facilitate the identification of prerequisites. A software management system (COMMES) is used to enhance the usefulness of these complex and extensive bodies of information. Additionally, study guides, personalized clinical instruction, instruction in human values, and information/resource sharing are part of the approach. (SW)

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TOTAL-SYSTEM DESIGN:
PLANNING, DELIVERING, AND SHARING INSTRUCTION ORIENTED TO PROFESSIONAL PRACTICE AND HUMAN VALUES

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Abstract

This paper explores aspects of the Total-System Design (TSD) approach to instructional design in medical laboratory science. TSD involves the application of systems science principles to the analysis of needs and to the delivery of instruction in educational programs. In concert with the other Creighton University health professions programs, our faculty members used a precise "language of instruction" and a "top-down" approach to define the knowledge, skills, and attitudes essential to entry-level generalist practice in medical laboratory science. The resulting total program description is detailed, uniform, and comprehensive. It is the logical basis for educational programs which address individual student needs within a broad view of professional responsibility. Use of a concurrently developed computer system permits powerful program analysis as well as personalized curriculum assembly. This has important implications beyond traditional formal education, including the support of individual career mobility and continuing education. The TSD approach with its associated computer system can enhance opportunities for communication, cooperation, and collaboration throughout the medical laboratory science community.

INTRODUCTION

In April, 1977, Creighton University began a major project involving all of its health science schools and programs. The Total-System Design Project[3] introduces new approaches to the design and delivery of health sciences instruction. The project combines the efforts of faculty members across the breadth of the health sciences, including programs preparing physicians, nurses, pharmacists, clinical pharmacists, dentists, nurse anesthetists, and medical technologists. Adopting analytical and problem-solving methodology from diverse disciplines, the Total-System Design (TSD) Project demonstrates an innovative approach to planning, delivering, and sharing health sciences instruction. Completion of the four-year research-and-development phase of the project provides an occasion to report upon application of the TSD process to medical laboratory science.

METHODOLOGY OF TOTAL-SYSTEM DESIGN

The Instructional Language

Any instruction (or transfer of information) can of course be described by a statement of its expected outcome. The Total-System Design involves the extension and adaptation of the familiar behavioral objectives to produce formal goal statements with several parts. A unit of instruction is first described by a statement of its purpose ("to enable the student to . . ."). This purpose statement is made more definite by specifying its

1. Complexity: the superficiality or depth of subject matter

presentation (Figure 1)

2. Mastery: the performance level at which the student will be tested (Figure 2)

3. Intensity: the relative difficulty of the unit in terms of concentration and initiative required (Figure 3)

The formal goal statement also includes specification of media type (such as reading, lecture, tutorial, audiovisual, applied laboratory, or clinical practicum) and estimates of contact time and study/practice time (Figure 4).

The system of formal instructional goals (each including its several qualifiers) makes up a precise "language of instruction" which enhances the value of behavioral objectives as instruments of communication.

The Top-Down Analytical Process

Total-System Design applies a systems science approach to needs analysis. The logical structure of an educational program can be discovered or specified using the "top-down" process of analysis-by-disassembly.[5] The analytical process begins with the concept of an "ideal" entry-level practitioner (graduating student). A formal goal statement is drafted to describe the plan of study preparing this hypothetical "ideal" technologist. The principal components of this plan of study similarly are described by formal goal statements. Each statement is further and further specified by a branching "tree" of sub-statements until the "content" level is reached. Specific instructional activities exist or are designed which fulfill each of these "content"

goals.

Total-System Design also facilitates the identification of prerequisites; these are the specific information or skills which students need in order to begin units covering aspects of medical technology practice. Prerequisites are specified through the analysis of every content goal. These prerequisite requirements are also stated as formal goals. This information provides the logical basis for planning pre-professional programs in which requirements in natural science, mathematics, and other areas are directly linked to and governed by practice needs.

The Computer Support System

The complete definition of an entire health science educational program (a "program definition") consists of thousands of formal goals arranged in a hierarchy. Their associated prerequisite goals may themselves have subgoals and pre-prerequisites. The COMMES (Creighton Online Multiple Medical Educational Services) software system[2] is a management information system that enhances the usefulness of these complex and extensive bodies of information.

COMMES provides the services of an automated educational consultant.[1] It uses artificial intelligence techniques to "understand" even poorly posed questions. COMMES clarifies the needs of its users and matches these needs to specific educational activities, producing personalized mini-curricula. The formal program definitions of health professions educational programs are the databases which provide compatible building blocks for the system's recommendations.

APPLICATION TO MEDICAL LABORATORY SCIENCE

The Medical Technology Program Definition

We applied the methodology of the Total-System Design to produce the complete, systematic definition of a program of study to prepare entry-level generalist practitioners in medical technology. The complete Medical Technology Program Definition consists of a hierarchical arrangement of goals, subgoals, sub-subgoals, and so on, describing the structure and instructional content of the program with greater and greater specificity. The document exceeds 200 pages. Tree diagrams in which each labelled node corresponds to a goal allow one to easily examine the relationships of goals comprising the medical technology major (Figure 5). One may similarly follow a single "thread" to the content level (Figure 6). We drafted formal instructional goals for every node of the tree diagrams. The very detailed goals of the fully-developed program definition, describing 15-to-30-minute units of instruction, are the basis for

1. listing the requirements for the major in medical technology

2. selecting or designing specific instructional experiences tailored for the fulfilment of each goal

3. determining appropriate means for evaluation, examination, or documentation of progress

4. sharply defining the knowledge and skills (i.e., the prerequisites) needed to undertake units of instruction within the major

Once this baseline is completed, it is a straightforward undertaking to use the same information to extend the definition to advanced levels and specialty areas or to define instruction for supporting more limited practice.

We use the Medical Technology Program Definition as the description of a medical technology major within a four-year curriculum leading to the Bachelor of Science in Medical Technology degree.

Study Guides Derived from the Program Definition

We used the Medical Technology Program Definition to produce study guides. For every content-level goal we specified media citations in the form of references to textbooks, nonprint instructional resources, discussion sessions, laboratory exercises, practical experiences, and so on. Each was selected or designed to permit the student to fulfill the corresponding content-level goal.

These study guides extend the language of instruction to the least experienced participant (the student), and thus complete a final level of communication about instruction. Study guides totalling approximately 700 pages are presently in place to support the 40 semester hours of instruction (1760 contact hours) which comprise our medical technology major.

DISCUSSION

Practice-Oriented Program Requirements

As we began and continued the process of program definition in medical technology, we addressed several critical challenges. We wished to define a rigorous major in medical laboratory science within a four-year program of study. Planning a major of reasonable size and maintaining a balance among supporting courses implied imposing some limitations. To apply an "essentialness" test at every decision point was, in our view, a rational way of handling these challenges.

Thus we worked to define a major in which the required achievements by students are as relevant to practice needs as possible. We asked our faculty members to answer the question, "According to your best recommendation, with what essential information, skills, and attitudes should the beginning practitioner (graduating student) be equipped?" Key "pruning" decisions involved recognition of the fact that the information and skills essential for a beginning practitioner constitute a definable subset of medical laboratory science itself. We used TSD as a powerful tool for testing the essentialness of instructional goals and for relating requirements to practice needs. Aspects of advanced or specialty areas (the "nice-to-know" material) can be offered as optional units.

We are also strongly committed to "the education of the total person" in the liberal arts tradition of Creighton University. The TSD method for deriving prerequisites from practice-oriented goals provides a logical basis for selecting pre-professional courses corresponding to defined needs. The potential exists for fine-tuning pre-

professional requirements (and course offerings) so that maximum flexibility is retained for selecting courses which contribute to breadth and satisfy individual student interests.

In the program of study which we defined, every requirement is derived from the program's top-level goals. These top-level goals in fact define competent entry-level practice. The "top-down" analytical process of TSD permits planning a program of instruction which is remarkably free of omissions and nonessentials, addressing needs for completeness and for reducing barriers to student progress.[6]

Personalized Instruction in Clinical Environments

We are using the study guides derived from our TSD efforts to support gradual but substantial changes in the delivery of instruction, which formerly relied on an intensive tutorial method. Students working in small groups use recommended resources to cover theoretical material. Discussion with the instructor and suitable integrative experiences follow. This approach has important implications. Students are encouraged to assume more active roles of greater responsibility, while persons who are primarily laboratory science practitioners are encouraged to fulfill resource-person and instructional manager roles. Further development will permit the pace, choice of resources, and amount of instructor support to be personalized according to the needs of each student.

There is considerable flexibility in the ways that study guides can be used. Possibilities range from the support of traditional lecture courses to their use in completely self-directed learning. They are in fact a detailed, flexible information base for the planning as well as the delivery of educational services.

Interdisciplinary Instruction in Human Values

The environment of the Total-System Design Project placed health care professions in a broader context of interdependence and professional responsibility. We were encouraged to address what was termed the "professional domain" in formulating our top-level goals. Development of these "professional domain" goals unfolded as an interdisciplinary effort. Faculty members from throughout the university contributed their expertise. These included experts in bio-ethics, sociological aspects of health care, biomedical research, legal issues in health care, and human behavior in organizational settings.

As a result defined needs for medical technology include

1. development of medical technology as a profession, including current issues affecting its perception and practice

2. health care policies and practices from an ethical perspective

3. legal issues affecting medical technology practice

4. evaluation of health-related research literature, including principles of research design and biostatistics

5. application of management theories and techniques

6. interdependence of health care professions

Instruction in these topics (90 contact hours) often involves non-health-sciences faculty members and heterogeneous groups of students. We believe that the goals for these areas provide an appropriate orientation for the Medical Technology Program in terms of professional responsibility and human values.

Sharing Information and Resources

The COMMES software system facilitates a range of activities, including the access, analysis, updating, and sharing of information about health sciences instruction. The system uses the formal definitions of the health sciences programs to construct curricula tailored to the individual needs of its users. Existing self-instructional units (audiovisual materials, learning packages, and so on) as well as "live" presentations (workshops, for example) can be described in TSD format and included among the building blocks for the system's responses.

Educators can benefit from the effort and expertise of even distant colleagues. They can locate sharable units of instruction as an alternative to re-inventing them. Students can pursue independent learning to a far greater extent. Practicing professionals can obtain personalized mini-curricula to support specific job-related goals. They can also use the same system for instructional self-assessment, using the system's recommendations as a basis for choosing among continuing education options.

The COMMES software system uses information gathered in the TSD process to deliver services to a user community of planners, administrators, instructors, students, and practicing professionals. With multiple educational programs and clinical sites linked in a computer network, COMMES can help to fulfill a recognized need for the

sharing of information and resources.[4]

CONCLUSION

This paper has described the application of new methodology to the planning and delivery of instruction in medical laboratory science. Participating in a four-year project involving the other Creighton University health sciences schools and programs, we used Total-System Design principles to produce the uniform, systematic, and complete definition of a medical technology major within a program of study leading to the B.S.M.T. degree. This formal program definition is central to the activities associated with the delivery of instruction to students through detailed study guides and the manipulation and sharing of information about instruction (goals, resources, assessment, and so on) through a computer support system.

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COMPLEXITY

Cognitive domain	OR	Psycho-motor domain
overview: highlights and perspectives	-1-	simple motor skill: easy repetitive movements needed
introduction: perspectives and some essential principles	-2-	applied motor skill: care and dexterity required
	-3-	
intermediate: virtually all essential principles plus a few topics in depth	-4-	involved motor skill: coordinated and involved, multiple manipulations necessary
	-5-	
advanced: all principles plus the majority of topics in depth	-6-	complex motor skill: requires choice of methods or alternative manipulations plus added dexterity
most advanced: great depth in virtually all topics	-7-	most complex motor skill: strength, endurance, and/or extreme dexterity needed

Figure 1: Rating scale for complexity, the degree of superficiality or depth of the presentation of subject matter

MASTERY

Cognitive domain	OR	Psycho-motor domain
recognition: can recognize information/material	-1-	lowest competency: slow and awkward
recall: can recall information/material	-2-	moderate competency: not as slow with moderate precision and accuracy
	-3-	
application: can adapt learning for application to unfamiliar situations	-4-	intermediate competency: methodical and meeting all minimum standards of precision and accuracy
	-5-	
synthesis: can derive new knowledge or arrive at new solutions	-6-	advanced competency: good speed, with precision, accuracy, and finesse
research: can extend frontiers of knowledge or invent new approaches	-7-	highest competency: maximum speed, precision, and accuracy, with elegance

Figure 2: Rating scale for mastery, an indication of the performance to be expected when the student is tested for achievement of the goal

INTENSITY

lowest intensity: the instruction demands little initiative

moderate intensity: the instruction demands moderate initiative and concentration

intermediate intensity: an average level of initiative and concentration

high intensity: substantial initiative, concentration, and independent learning required

stongest intensity: intense initiative and concentration required

Figure 3: Rating scale for intensity, the relative difficulty of the unit in terms of concentration and initiative required

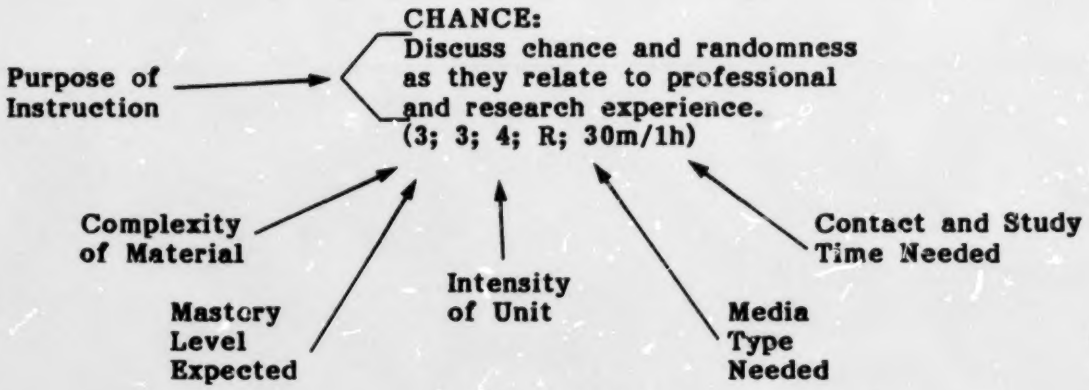
CHANCE:
Discuss chance and randomness as they relate to professional and research experience.
(3; 3; 4; R; 30m/1h)
Purpose of Instruction
Complexity of Material
Mastery Level Expected
Intensity of Unit
Media Type Needed
Contact and Study Time Needed

Figure 4: Parts of a formal instructional goal

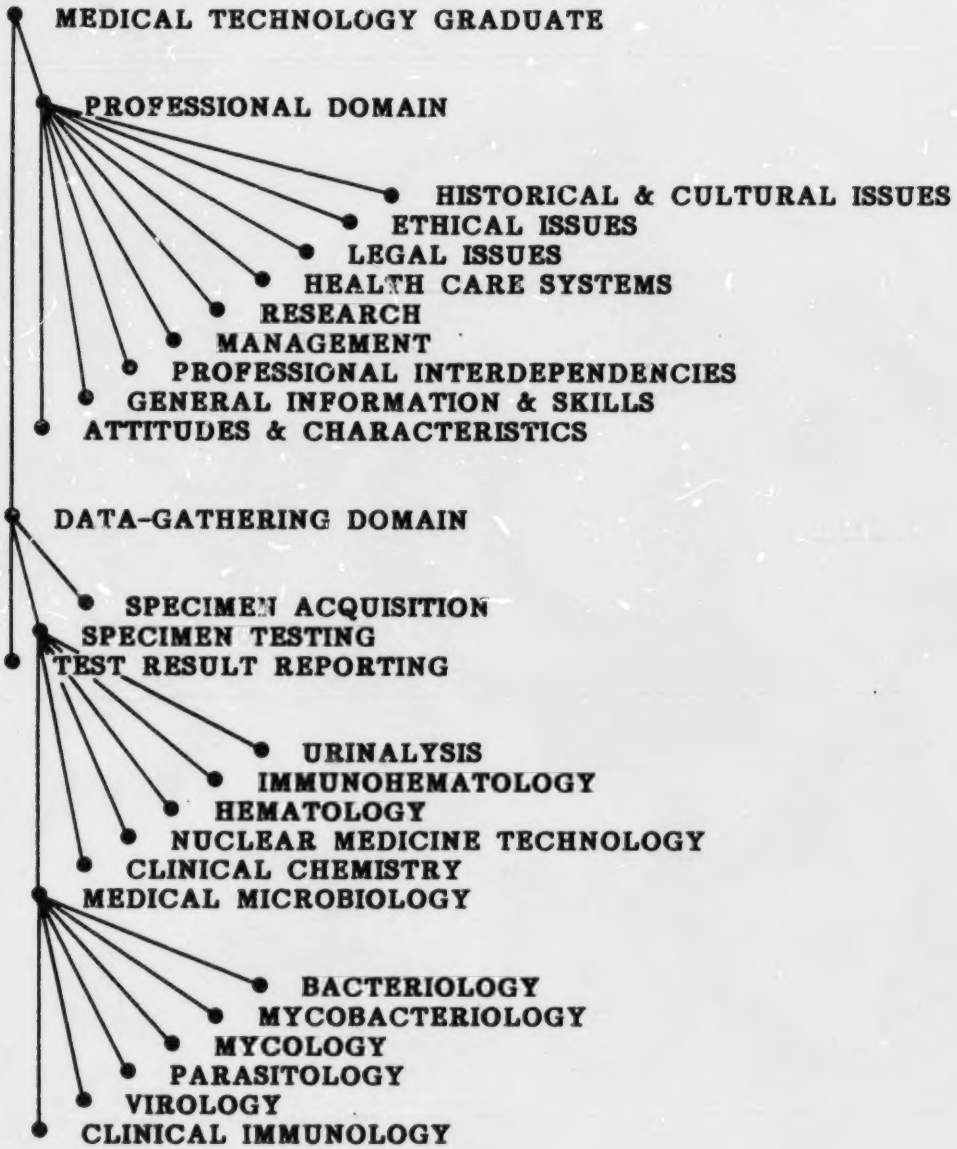

Figure 5: A structural overview of goals comprising the Medical Technology major

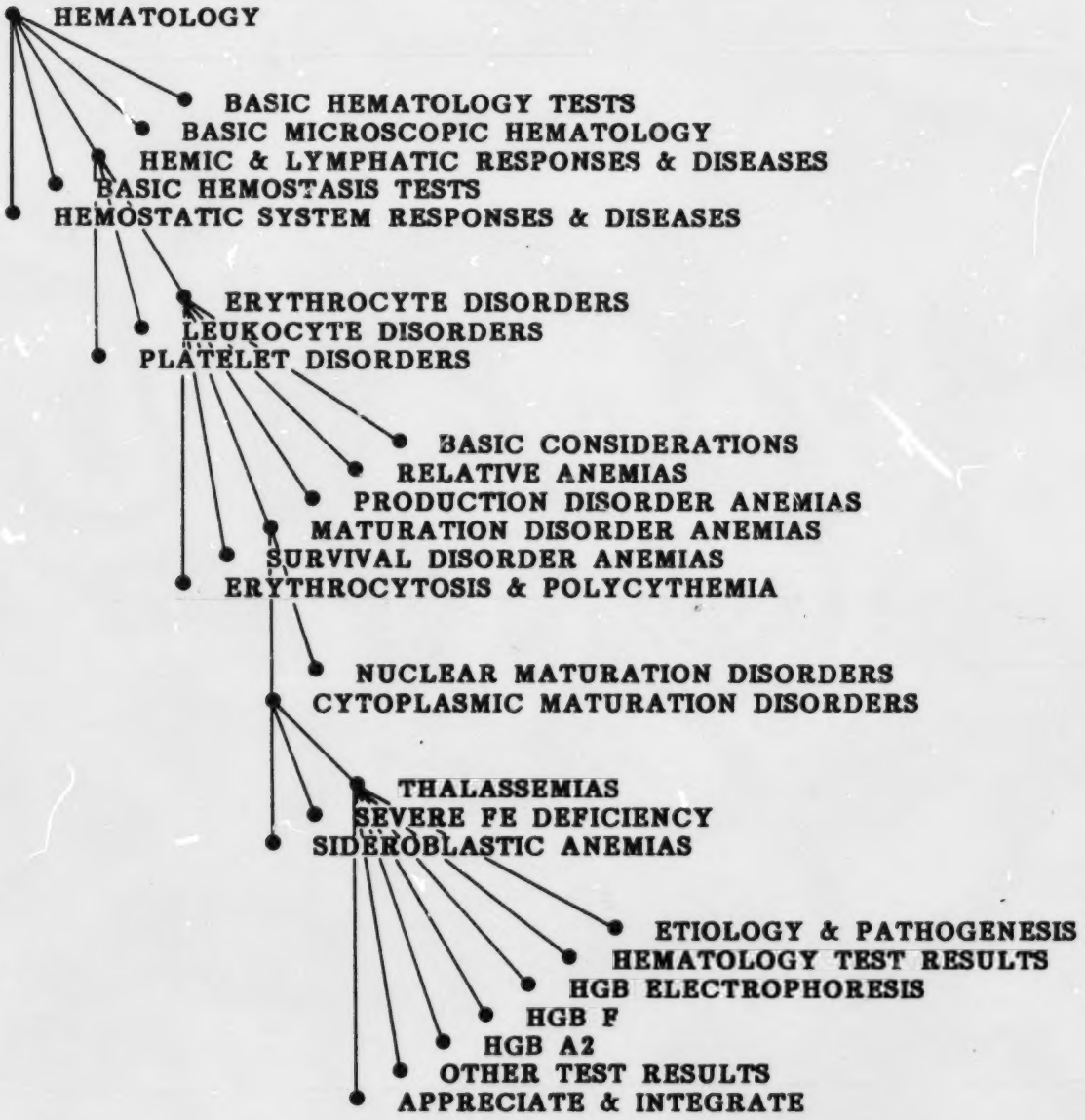

Figure 6: Development of a single "thread" in Hematology to the content level